

United States Patent Application for:

DETACHABLE ELECTROSTATIC CHUCK

Inventors:

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|---|---|
| 1) Karl Brown
A citizen of the United Kingdom,
104 Oakhaven Place,
Mountain View, CA 94041,
U.S.A.; | 5) Cheng-Hsiung Tsai
A citizen of the Republic of
China,
22332 Bahl Street,
Cupertino, CA 95014,
U.S.A.; |
| 2) Nora Arellano
A citizen of the United States of
America,
1250 Henderson Avenue,
Sunnyvale, CA 94086,
U.S.A.; | 6) Vineet Mehta
A citizen of India,
908 Tamarack Lane, No. 5,
Sunnyvale, CA 94086,
U.S.A.; |
| 3) Semyon Sherstinsky
A citizen of the United States of
America,
742 32 nd Avenue,
San Francisco, CA 94121,
U.S.A.; | 7) Steve Sansoni
A citizen of the United States of
America,
189 Ponte Court,
Livermore, CA 94550,
U.S.A. and |
| 4) Allen Lau
A citizen of the United States of
America,
839 September Court,
Cupertino, CA 95014,
U.S.A.; | 8) Wei W. Wang
A citizen of the People's
Republic of China,
2201 Monroe Street #804,
Santa Clara, CA 95050,
U.S.A. |

Assignee:	Applied Materials, Inc.
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DETACHABLE ELECTROSTATIC CHUCK

BACKGROUND

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Embodiments of the present invention relate to an electrostatic chuck for holding a substrate in a process chamber

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In the processing of substrates, such as semiconducting wafers and displays, the substrate is placed on a support in a process chamber and suitable processing conditions are maintained in the chamber. The support can include an electrostatic chuck that has an electrode capable of being electrically biased to hold the substrate on the support. The electrode may also be electrically biased, for example with an RF bias power, to energize a process gas in the chamber to process the substrate. The support can also comprise a pedestal that supports the electrostatic chuck in the chamber, and may be capable of raising or lowering the height of the electrostatic chuck and substrate. The pedestal can also provide a protective enclosure for connecting wires, gas tubes etc, that connect to portions of the support.

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In a typical chamber process, energized gases are used to process substrates by, for example, etching or depositing material on the substrate, or to clean surfaces in the chamber. These energized gases can comprise highly corrosive species, such as chemical etchants, as well as energized ionic and radical species that can erode away portions of the support, such as an electrostatic chuck composed of aluminum nitride. The eroded support can be problematic because the damaged support may not provide the desired electrical characteristics for processing substrates or holding substrates on the support. Also, particles that have eroded from the support can contaminate substrates being held on the support.

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An example of a conventional support having improved resistance to erosion comprises an electrostatic chuck made of a ceramic, such as aluminum nitride, and having an embedded electrode that is brazed to an underlying stainless steel pedestal, as described in U.S. Patent No. 6,563,686 to Tsai et al, filed on March 19, 2001 and commonly assigned to Applied Materials, which is herein incorporated by

reference in its entirety. Electrostatic chucks made of ceramics are desirable because they have improved resistance to corrosion by energized process gases, and can maintain their structural integrity even at high substrate processing temperatures exceeding several hundred degrees centigrade. However, a problem with conventional supports is that thermal expansion mismatch can occur between the ceramic electrostatic chuck and the supporting pedestal, especially during substrate processes conducted at high temperatures. The difference in thermal expansion coefficients of ceramic materials and the metal pedestal materials can result in thermal and mechanical stresses that can cause the ceramic to fracture or chip.

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One solution to the thermal expansion mismatch problem is described in U.S. Patent No. 6,490,146, entitled "Electrostatic chuck bonded to base with a bond layer and method", to Shamouilian et al, filed on May 7, 1999, and commonly assigned to Applied Materials, Inc, which is herein incorporated by reference in its entirety. The support described by Shamouilian et al. has a ceramic electrostatic member having an electrode that is attached to a base beneath the electrostatic member. The base is made of a composite of a ceramic and a metal that has a coefficient of thermal expansion that is sufficiently close to that of the electrostatic member to reduce thermal expansion stresses, for example, a difference of less than 10%. The ceramic electrostatic member and base are typically brazed together to provide a strong bond between the electrostatic member and base. The base can be secured in the chamber by attaching the base to an underlying support via a metal bond layer.

However, even these advanced substrate supports can eventually require replacement or refurbishment when they erode or have accumulated process deposits that require extensive cleaning after exposure to multiple plasma processing cycles. Sometimes, the entire support has to be replaced, so that a substrate will not become contaminated by flaked particles of process residue or that arise from damaged portions of support, and to ensure that the desired electrical properties of the support are maintained consistent. The replacement of the entire support can be both costly and wasteful. For example, a replacement substrate support can cost tens of thousands of U.S. dollars, and the support may need to be replaced, on average, after the processing of 50,000 to 100,000 substrates, increasing processing costs. The

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support may also need to be replaced if misuse or accidental operation damages the support surface or edges.

5 Thus, it is desirable to have a substrate support that exhibits reduced thermal expansion mismatch problems. It is furthermore desirable to have a substrate support that does not require replacement of the entire support as frequently as conventional supports. It is also desirable to have a substrate support that does not incur replacement costs that are as high as those of conventional supports.

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SUMMARY

An electrostatic chuck is capable of attachment to a pedestal in a process chamber. The chuck has an electrostatic puck comprising a ceramic body with an embedded electrode. The ceramic body has a substrate support surface with an annular periphery. A base plate below the electrostatic puck comprises a composite of a ceramic material and a metal, and has an annular flange extending beyond the periphery of the ceramic body. The annular flange extension allows the chuck to be more easily attached and removed from the chamber.

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In one version, the base plate is a composite that is a ceramic infiltrated with a metal, and has an annular flange with a plurality of holes that are shaped and sized to allow connectors to pass therethrough. The chuck has a support pedestal having a housing and an annular ledge that extends outwardly from the housing. The annular ledge is capable of being attached to the annular flange of the base plate by the connectors.

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In yet another version, the electrostatic chuck has a heat transfer plate below the base plate that is at least partially surrounded by the pedestal housing. The heat transfer plate has an embedded heat transfer fluid channel. The chuck also has a spring assembly at least partially surrounded by the housing that can be biased to press the heat transfer plate against the base plate.

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DRAWINGS

These features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims,
5 and accompanying drawings, which illustrate examples of the invention. However, it is to be understood that each of the features can be used in the invention in general, not merely in the context of the particular drawings, and the invention includes any combination of these features, where:

10 Figure 1 is a sectional side view of an embodiment of an electrostatic chuck comprising a base plate with an annular flange attached to a pedestal ledge;

 Figure 2 is a sectional top view of an embodiment of a heat transfer plate having a heat transfer fluid channel; and

15 Figure 3 is a partial sectional schematic side view of a version of a chamber having the electrostatic chuck.

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DESCRIPTION

An electrostatic chuck 20 comprises an electrostatic puck 22 having a chargeable electrode 24 that can electrostatically hold a substrate 104 in a substrate processing chamber 106, as illustrated in the exemplary chamber embodiment of Figure 1. The electrostatic puck 22 comprises a ceramic body 26 having an electrode 24 embedded therein. The ceramic body 26 comprises a substrate support surface 28 that holds the substrate 104 on the chuck 20, and can comprise a disc-like shape with an annular periphery 48. The electrode 24 is capable of being electrically biased to electrostatically hold the substrate 104 on the surface 28. For example, the electrode 24 can be connected via an electrical connector 30 to an electrode power supply 81 that delivers a DC chucking voltage, as shown in Figure 3. The electrode 24 may also be capable of being electrically biased to energize a process gas in the chamber to process the substrate 104 or clean the chamber 106. For example, the electrode power supply 81 may be capable of providing an RF bias to the electrode 24 to capacitively couple energy to a process gas. The ceramic body 26 desirably comprises a material that is permeable to electromagnetic energy, such as for example at least one of aluminum nitride, aluminum oxide, and titanium oxide, and preferably comprises aluminum nitride.

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The electrostatic chuck 20 can further comprise a pedestal 32 to support the electrostatic puck 22 and substrate 104 in the chamber 106. The pedestal 32 comprises a housing 34 to protect portions of the electrostatic chuck 20 from the process environment. The housing 34 comprises sidewalls 38 and a bottom wall 66 that surround an interior enclosure 35 to protect components within the enclosure, such as for example electrical connectors, gas tubes and fluid conduits. The pedestal 32 further comprises a ledge 40 that extends outwardly from the top of the housing sidewall 38 to provide a projecting support for the electrostatic puck 22. The pedestal housing 34 can comprise a metal that is resistant to corrosion in the substrate processing environment, such as for example, at least one of stainless steel and titanium. The pedestal 32 can also comprise a pedestal column 33 that extends between the housing 34 and the chamber 106. Electrical connectors, gas conduits and fluid conduits can be passed through the column 33 to protect them from the

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processing environment. A bellows assembly 36 can also be provided to raise and lower the electrostatic puck 22 and substrate 104 in the chamber 106.

The electrostatic chuck 20 further comprises a base plate 42 below the electrostatic puck 22 that connects the electrostatic puck 22 to the pedestal 32. The base plate 42 comprises a disc-like main portion 43 underneath the ceramic body 26, and an annular flange 46 that extends outwardly from the main portion 43 along the ledge 40 of the pedestal 32. The annular flange 46 extends beyond the periphery 48 of the ceramic body 26 to provide an exposed portion of the base plate that is not covered by the ceramic body 26, and that can be attached directly to the pedestal 32. To connect the base plate 42 to the pedestal 32, the annular flange 46 comprises a plurality of holes 50 that are sized and shaped to allow a connector 44 to pass therethrough to connect to the pedestal ledge 40. For example, the holes 50 may extend vertically through a thickness of the annular flange 46, from a flange upper surface 41 to a flange lower surface 51. The holes 50 can also extend through at least a portion of the pedestal ledge 40 to secure the flange 46 to the ledge 40. A connector 44 suitable to connect the base plate 42 to the ledge 40 via the holes 50 can comprise, for example, at least one of a pin, bracket, bolt, screw, nail, and other similar object. For example, the connector 44 may comprise a threaded pin having a head 45 that is held on the top surface 41 of the annular flange 46, and a threaded lower end 47 that fits with a threaded hole 50 formed in the ledge 40 to secure the base plate 42 and pedestal 32 together.

The base plate 42 desirably comprises a material that is sufficiently strong to allow it to be secured to the pedestal 32 via the holes 50 substantially without cracking or breaking. In one version, the base plate 42 comprises a material that is a composite of a ceramic material and a metal. The composite material provides improved strength and durability over ceramic materials alone, such as AlN, and also has good heat transfer properties for the transfer of heat to and from the ceramic body 26 and substrate 104. The composite material also comprises a thermal expansion coefficient that is well matched to the ceramic body 26 to reduce thermal expansion mismatch between the ceramic body 26 and base plate 42. In one version, the composite material comprises a ceramic material having pores that are infiltrated with a metal. The infiltrated metal at least partially fills the pores in the ceramic to form a

composite material that has characteristics of both the ceramic and the metal, to provide improved material strength substantially without sacrificing good thermal matching properties. The ceramic material may comprise, for example, at least one of silicon carbide, aluminum nitride, aluminum oxide and cordierite, and preferably silicon carbide. The ceramic material may comprise a pore volume without the infiltrated metal of from about 20 to about 80 volume percent of the total ceramic volume. The infiltrated metal can comprise one or a mixture of aluminum, silicon, and copper, and preferably comprises aluminum. The infiltrated metal may comprise a volume percent of from about 20% to about 80% of the total composite material. In another version, the composite material may comprise a different composition of a ceramic and metal, such as a composite comprising a metal having ceramic particles dispersed therein.

In one version, the base plate 42 can be attached to the ceramic body 26 of the electrostatic puck 22 by a bond layer 54. In one version, the bond layer 54 comprises a suitable brazing material that is formed between a top surface 49 of the base plate 42 and a bottom surface 25 of the ceramic body 26. The base plate 42, bond layer 54 and ceramic body 26 are then heated to a sufficiently high temperature and under a sufficiently high pressure such that the bond layer brazing material diffuses into both the base plate 42 and ceramic body 26 to form a bond between the materials. The bond layer 54 desirably comprises a material that has thermal properties suitably matched to the ceramic body 26 and base plate 42. For example, the bond layer 54 can comprise a metal material such as aluminum.

The electrostatic chuck 20 having the base plate 42 comprising the composite material and having the annular flange 46 is an improvement over conventional substrate supports because the electrostatic chuck 20 allows for the electrostatic puck 22 and base plate 42 to be easily removed from the pedestal 32 when replacement or refurbishment of one or more of the electrostatic puck 22 and base plate 42 is required. Because the exposed annular flange portion of the base plate 42 is not covered by the relatively brittle ceramic body 26, the relatively strong composite material of the annular flange 46 can be detachably directly connected to the pedestal 32 to allow for easy removal of the puck 22 and base plate 42. For example, the electrostatic puck 22 and base plate 20 can be detachably connected to the pedestal 32 by inserting the connector 44 through the composite material of the flange

46 and into the pedestal 32. The puck 22 and base plate 42 can then be removed from the pedestal 32 by removing the connector 44 from at least one of the base plate flange 46 and pedestal ledge 40, when one or more of the puck 22 and base plate 42 has become excessively eroded or dirtied with process residues.

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The detachable electrostatic chuck 20 reduces the costs associated with processing substrates with the chuck 20 by allowing the electrostatic puck 22 and/or base plate 42 to be replaced or refurbished as needed, without requiring replacement of the entire chuck 20. The base plate 42 having the annular flange 46 provides
10 significant advantages in allowing the electrostatic chuck 20 to be directly attached to, while still easily removable from, the chamber 106. The base plate 42 and annular flange 46 can also be made from a material that is more ductile than the ceramic material of the electrostatic puck 22, to reduce the effect of thermal expansion mismatches between the chuck 20 and the underlying pedestal 32. Also, because the
15 annular flange 46 extends outwardly from the base plate 42, an operator can more easily see and access the bolts positioned on the annular flange 46, allowing the operator to more easily remove the chuck 20 from the chamber 106 when it requires cleaning, servicing, or refurbishment. In the prior art, the chuck 20 was joined to the pedestal 32 by a bond or metal braze so that the entire assembly including the pedestal
20 32 had to be removed from the chamber 106. Also, it was more difficult to reach down to the bottom of the chamber to access the underlying attachment components to remove the entire assembly. Removal of the entire prior art assembly from the chamber 106 can also result in possibly increased contamination of the larger surface or volume of components outside the chamber 106. In contrast, the present chuck 20
25 provides easier removal access, reduced thermal expansion mismatch stresses, and a smaller volume of components to remove from the chamber 106.

The electrostatic chuck 20 can further comprise other elements that improve substrate processing, such as for example, a thermocouple 80 having a
30 temperature sensing end that is embedded in the electrostatic puck 22. The thermocouple 80 can connect to a temperature monitor, such as a chamber controller 194, to monitor the temperature of the chuck 20 and substrate 104 during processing. The electrostatic chuck 20 can also comprise heat transfer gas outlets 76 on the surface 28 of the electrostatic puck 22 to deliver a heat transfer gas, such as nitrogen,

to the backside of a substrate 104. The heat transfer gas outlets 76 can feed channels (not shown) formed on the support surface 28, and can be connected via a conduit 74 to a heat transfer gas supply 75. A gas tube 72 can be inserted into the electrostatic puck 22 to define a path for the heat transfer gas through the puck 22, and to provide a
5 desired flow of the heat transfer gas to the support surface 28.

In one version, the electrostatic chuck 20 further comprises a heat transfer plate 56 capable of transferring heat to or from the electrostatic puck 22 and substrate 104 to provide desired substrate processing temperature conditions. For
10 example, the heat transfer plate 56 may comprise a cooling plate to cool the substrate 104 to a desired temperature, or to maintain a desired substrate temperature during processing. The heat transfer plate 56 can comprise at least one fluid channel 58 through which a heat transfer fluid can be flowed to control the temperature of the heat transfer plate 56. The heat transfer fluid is supplied by a fluid supply 57 connected to
15 the fluid channel 58 via one or more conduits 61 that can be routed through the column 33 of the pedestal 32. The heat exchange plate 56 desirably extends beneath a substantial portion of the substrate receiving surface 28, such as for example from at least about 25% to about 85% of the substrate receiving surface 28, to provide good heat exchange with the substrate 104. The heat transfer plate 56 can be made of a
20 thermally conductive material such as a metal, for example, at least one of copper, stainless steel and aluminum.

In one version, the heat transfer plate 56 comprises improved fluid channels 58 that provide enhanced cooling/heating of the heat transfer plate 56. In the
25 version shown in Figure 2, the fluid channels 58 are embedded in the heat transfer plate to provide improved heating/cooling of the plate 56. The fluid channels 58 comprise a fluid inlet 64a that is located at an interior region 59 towards the center 73 of the plate 56, and that receives the heat transfer fluid from the connecting conduit 61. The fluid inlet 64a feeds a first spiral channel 58a that spirals outwardly from the fluid
30 inlet 64a towards a periphery 63 of the heat transfer plate 56. The first spiral channel 58a desirably encircles the interior region 59 and center 73 more than once, such as at least about 3 times. A second spiral channel 58b connects to the first spiral channel 58a near the periphery of the plate 56, and runs adjacent to the first spiral channel 58a to trace a second spiraling flow path back to a fluid outlet 64b that is towards the center

73 of the plate 56. Thus, the spiral channels 58a,b provide opposing spiral flows of the heat transfer fluid through the heat transfer plate 56. The spiral channels 58a,b also provide a substantially horizontal flow of fluid through the heat transfer plate 56 to extend to a larger region of the plate 56. The improved fluid flow channel configuration provides improved temperature control of the heat transfer plate 56 by thermally contacting a large area of the heat transfer plate 56.

In one version, the heat transfer plate 56 is formed by attaching first and second plate portions 71a,b. For example, the heat transfer plate 56 may comprise a first plate portion 71a comprising a first material, and a second plate portion 71b below the first plate portion 71a that comprises a second material. The first plate portion 71a may comprise a first material having good heat transfer qualities to transfer heat to the substrate 104, such as for example copper. The second plate portion 71b may comprise other beneficial characteristics, for example, the second plate part 71b may be a material that comprises a high strength, such as stainless steel. The first and second plate portions 71a,b can be joined together by a conventional bonding method, for example by heating the plate portions 71a,b to braze the portions together. The fluid flow channel 58 is desirably embedded in one or more of the plate portions 71b, and is preferably at least partially embedded in the first plate portion 71a. In one version, the fluid flow channel 58 is formed by machining or otherwise forming an open channel in the first plate portion 71a, and brazing the second plate portion 71b over the open channel to form the closed fluid flow channel 58.

A thermally conductive layer 60 can be provided between the base plate 42 and the heat transfer plate 56 to enhance heat exchange therebetween. The thermally conductive layer 60 conforms to the top surface 65 of the heat transfer plate 56 and the bottom surface 67 of the base plate 42. In one version, the thermally conductive layer 60 comprises an interstitial material layer such as graphite, as described for example in U.S. Patent No. 6,563,686 to Tsai et al, filed on March 19, 2001, and commonly assigned to Applied Materials, which is herein incorporated by reference in its entirety.

In one version, the electrostatic chuck 20 can further comprise a spring assembly 62 adapted to apply a pressure to the heat transfer plate 56 to press the plate

56 against the base plate 42 and improve heat transfer therebetween. In the version shown in Figure 1, the spring assembly 62 comprises a plurality of vertically aligned springs 23 that are compressed between a bottom wall 66 of the pedestal housing 34 and the heat transfer plate 56. The springs 23 can be positioned at intervals along the bottom wall 66 to form one or more annular groupings of springs that apply pressure about a desired radius of the heat transfer plate 56. The spring assembly 62 can further comprise a compression ring 68 that rests on top of the springs 23 and has a pressing surface 69 that presses against the heat transfer plate 56. The spring assembly 62 desirably applies a force of from at least about 890 N (200 lbs) to about 1780 N (400 lbs) to the heat transfer plate 56 to improve heat transfer with the base plate 42 and electrostatic puck 22.

The electrostatic chuck 20 may also comprise springs in other areas of the assembly where it is desirable to apply pressure. For example, the electrostatic chuck 20 may comprise a plurality of gas tube springs 70 to support and stabilize the gas tube 72 in the portion of the gas conduit 74 formed in the electrostatic puck 22 and base plate 42. A plurality of springs 70 can be positioned on top of the heat transfer plate 56 and press on a lower surface 78 of the gas tube 72 to secure the gas tube in the gas conduit 74. The springs 70 help stabilize the gas tube 72 during varying process temperatures and process conditions that could otherwise lead to misalignment of the gas tube 72.

An embodiment of an apparatus 102 comprising a process chamber 106 suitable for processing a substrate 104 with the electrostatic chuck 20 is shown in Figure 3. The particular embodiment of the apparatus 102 shown herein is suitable for processing substrates 104 such as semiconductor wafers, and may be adapted by those of ordinary skill to process other substrates 104, such as flat panel displays, polymer panels, or other electrical circuit receiving structures. The apparatus 102 is particularly useful for processing layers, such as etch resistant, silicon-containing, metal-containing, dielectric, and/or conductor layers on the substrate 104. The apparatus 102 may also be attached to a mainframe unit (not shown) that contains and provides electrical, plumbing, and other support functions for the apparatus 102 and may be part of a multichamber system (not shown).

Generally, the process chamber 106 comprises a wall 107, such as an enclosure wall 103, which may comprise a ceiling 118, sidewalls 114, and a bottom wall 116 that enclose a process zone 108. In operation, process gas is introduced into the chamber 106 through a gas supply 130 that includes a process gas source 138, and a gas distributor 137. The gas distributor 137 may comprise one or more conduits 136 having one or more gas flow valves 134 and one or more gas outlets 142 around a periphery of the substrate 104, which is held in the process zone 108 on the electrostatic chuck 20. Alternatively, the gas distributor 130 may comprise a showerhead gas distributor (not shown). Spent process gas and process byproducts are exhausted from the chamber 106 through an exhaust 144 which may include an exhaust port 170 that receives spent process gas from the process zone 108 and delivers the gas to an exhaust conduit 177, a throttle valve 135 to control the pressure of process gas in the chamber 106, and one or more exhaust pumps 152.

The process gas may be energized to process the substrate 104 by a gas energizer 154 that couples energy to the process gas in the process zone 108 of the chamber 106. For example, the gas energizer 154 may comprises process electrodes, that may be powered by a power supply to energize the process gas. The process electrodes may include an electrode that is or is in a wall, such as a sidewall 114 or ceiling 118 of the chamber 106, that may be capacitively coupled to another electrode, such as the electrode 24 in the electrostatic chuck 20 below the substrate 104. Alternatively or additionally, the gas energizer 154 may comprise an antenna comprising one or more inductor coils which may have a circular symmetry about the center of the chamber 106. In yet another version, the gas energizer 154 may comprise a microwave source and waveguide to activate the process gas by microwave energy in a remote zone (not shown) upstream from the chamber 106.

In one version, the chamber 106 can comprise a physical vapor deposition chamber capable of sputter depositing material on a substrate 104. In this version, the chamber comprises a sputtering target 155 having material to be deposited on the substrate. The target 155 can be electrically biased with respect to another component in the chamber, such as a process shield, to act as a part of a gas energizer 154 that energizes the process gas and sputters material from the target 155 and onto the substrate 104.

To process a substrate 104, the process chamber 106 is evacuated and maintained at a predetermined sub-atmospheric pressure. The substrate 104 is then provided on the electrostatic chuck 20 by a substrate transport 101, such as for
5 example a robot arm and a lift pin system. The gas supply 130 provides a process gas to the chamber 106 and the gas energizer 154 couples energy to the process gas to energize the gas and process the substrate 104, for example by etching material on the substrate or depositing material on the substrate 104. Similarly, to clean the chamber after processing of the substrate 104, the gas supply 130 provides a process gas
10 comprising a cleaning gas to the chamber 106 and the gas energizer 154 energizes the cleaning gas to clean the chamber 106.

The chamber 106 is controlled by a controller 194 that comprises program code having instruction sets to operate components of the chamber 106 to process
15 substrates 104 in the chamber 106. For example, the controller 194 can comprise a substrate positioning instruction set to operate one or more of the electrostatic chuck 20 and substrate transport to position a substrate 104 in the chamber 106, and to set a chucking voltage applied by the electrode power supply 81 to hold the substrate 104 on the electrostatic chuck 20; a gas flow control instruction set to operate the flow control
20 valves 134 to set a flow of gas to the chamber 106; a gas pressure control instruction set to operate the exhaust throttle valve 135 to maintain a pressure in the chamber 106; a gas energizer control instruction set to operate the gas energizer 154 to set a gas energizing power level; a temperature control instruction set to control temperatures in the chamber 106, for example by controlling the supply of heat transfer fluid to the heat
25 transfer plate 56, and the supply of heat transfer gas to the support surface 28; and a process monitoring instruction set to monitor the process in the chamber 106, for example by monitoring temperatures via the thermocouple 80.

Although exemplary embodiments of the present invention are shown and
30 described, those of ordinary skill in the art may devise other embodiments which incorporate the present invention, and which are also within the scope of the present invention. For example, the annular flange 46 may be connected to the ledge 40 of the pedestal by means other than those specifically described. Furthermore, relative or positional terms shown with respect to the exemplary embodiments are

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interchangeable. Therefore, the appended claims should not be limited to the descriptions of the preferred versions, materials, or spatial arrangements described herein to illustrate the invention.

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